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Gorsuch

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(54) **DUAL MODE SUBSCRIBER UNIT FOR
SHORT RANGE, HIGH RATE AND LONG
RANGE, LOWER RATE DATA
COMMUNICATIONS**

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(52) **U.S. Cl.** **370/338; 370/333; 370/470;
455/552; 455/553**

(58) **Field of Search** **370/238, 237,
370/351, 352, 338, 470, 445, 447, 448,
349, 333, 465**

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Primary Examiner—Nguyen T. Vo

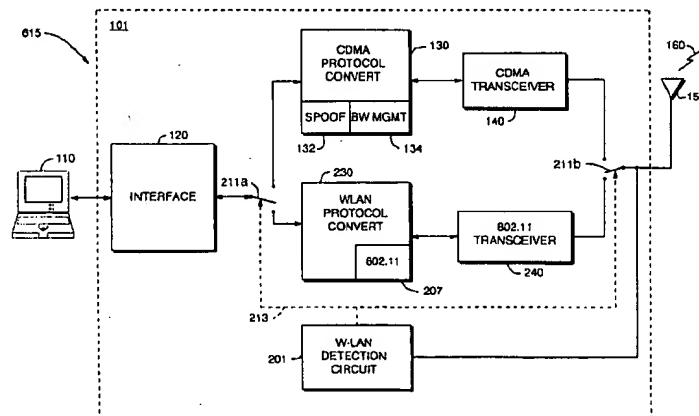
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(57) **ABSTRACT**

A technique for communicating with a local area network (LAN) via a wireless connection determines whether a first short-range, high-speed, wireless communication path is available and connects to the LAN using a longer range, lower speed wireless communication path if the short-range, high-speed wireless communication path is not available. The low-range, high-speed wireless communication path is a wireless LAN connection such as an IEEE 802.11-compliant wireless LAN and the long-range, low-speed wireless communication mode is a cellular CDMA-type connection. Determining whether the first IEEE 802.11 mode is available can be done by detecting a beacon signal, or by transmitting a probe request message and detecting a probe response message in response to the probe request, indicating the presence or availability of the short-range, high-speed wireless communication path. Alternatively, the availability of short-range, high-speed wireless communication path can be detected by simply detecting activity on it.

21 Claims, 6 Drawing Sheets



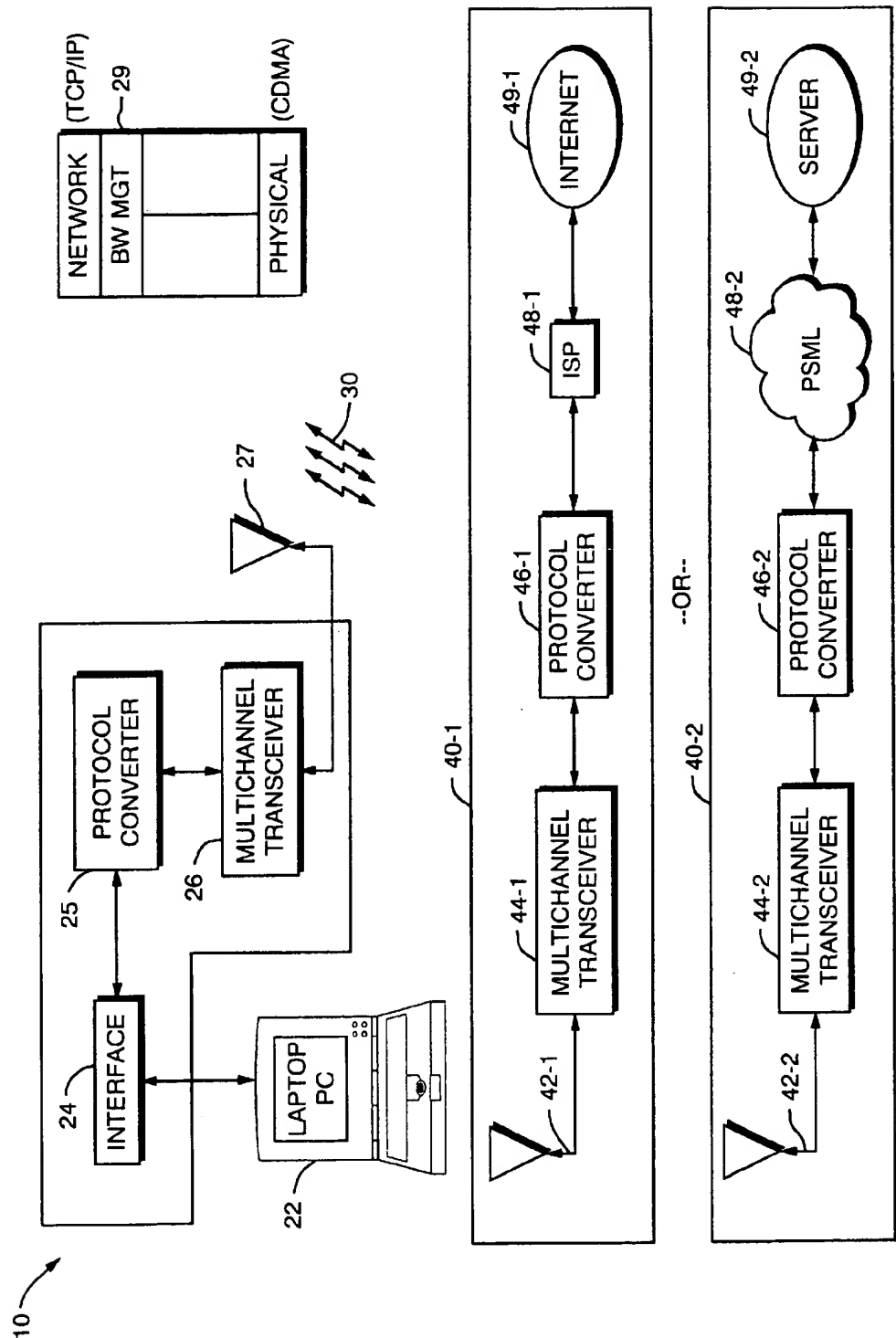


FIG. 1

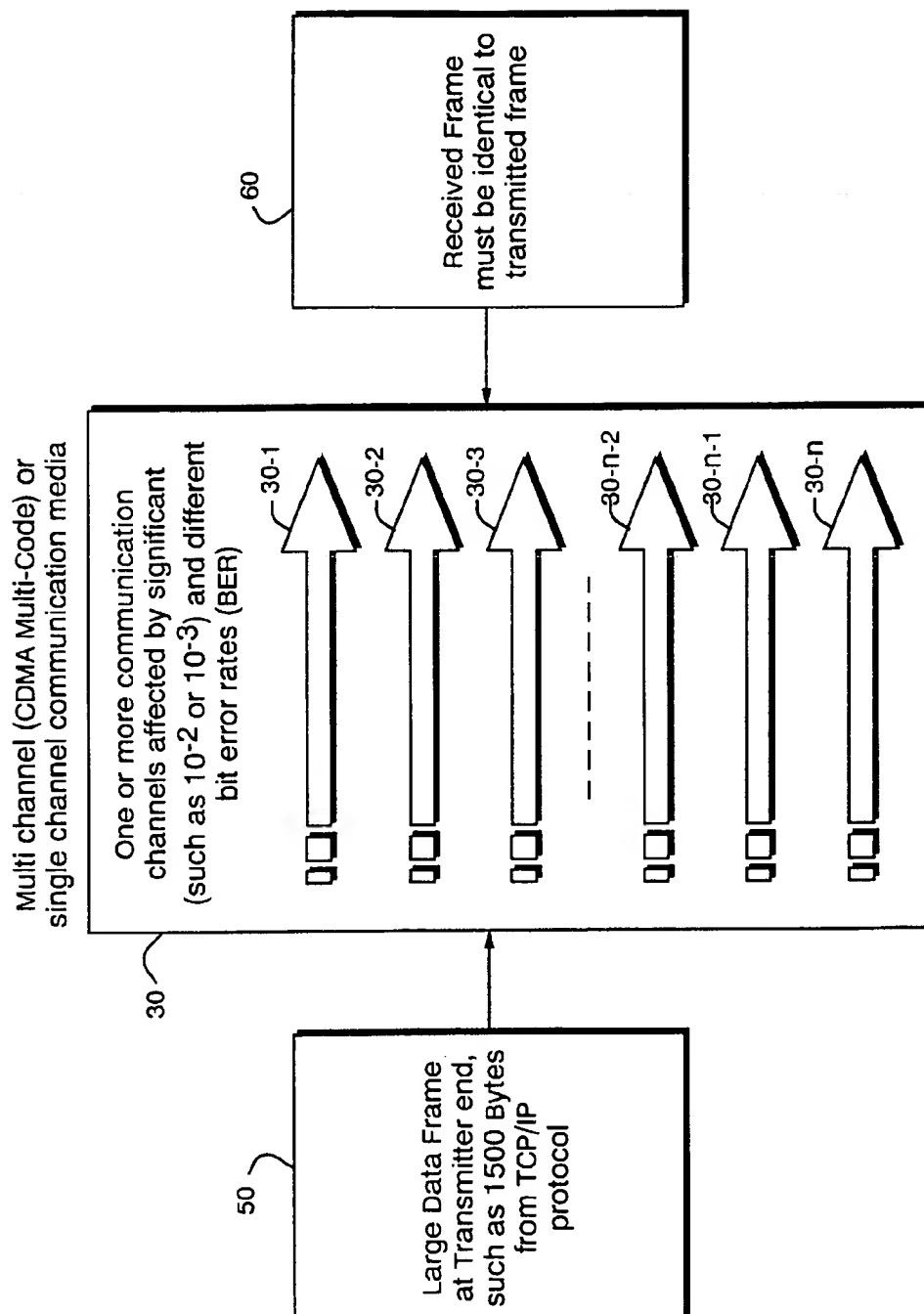
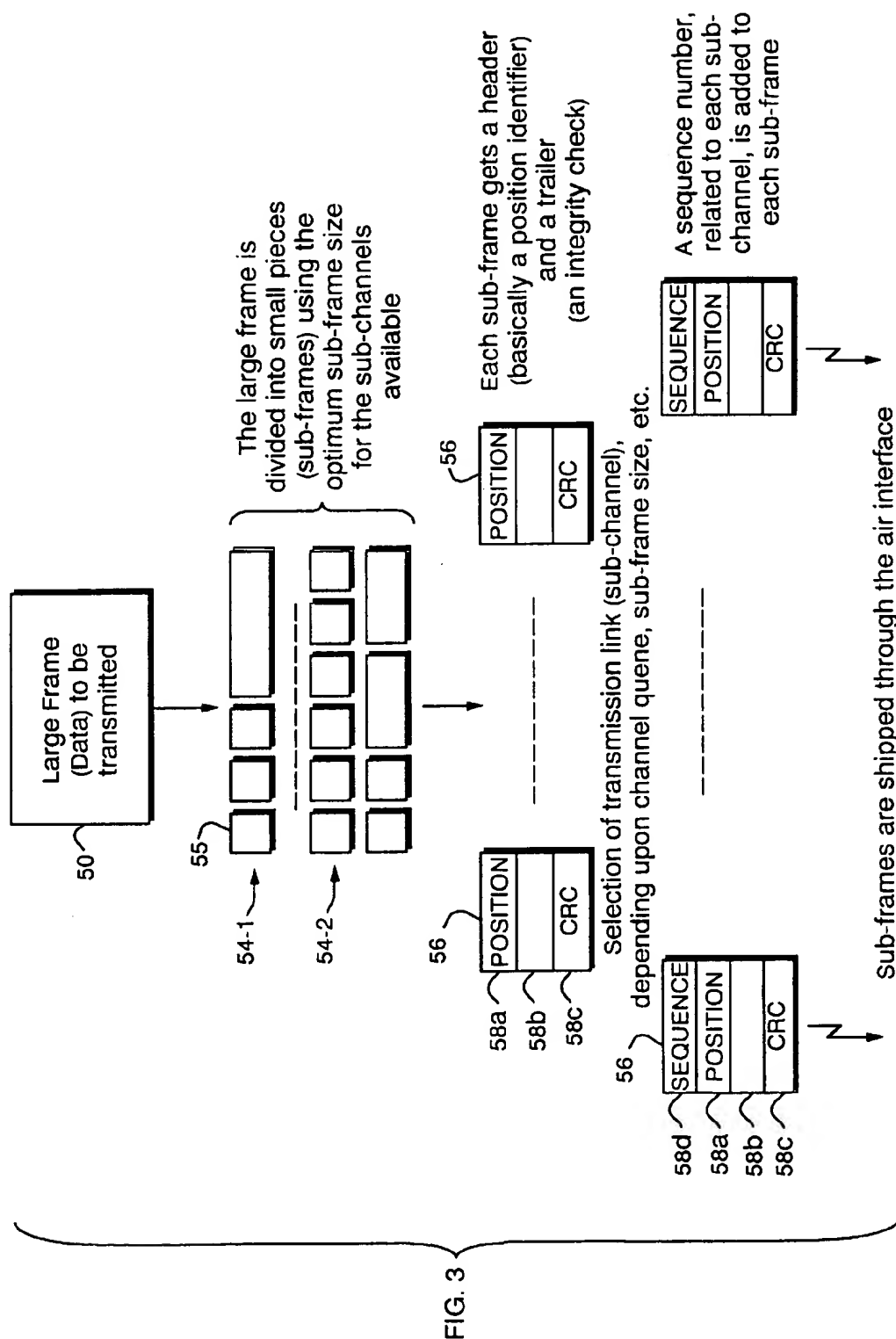


FIG. 2



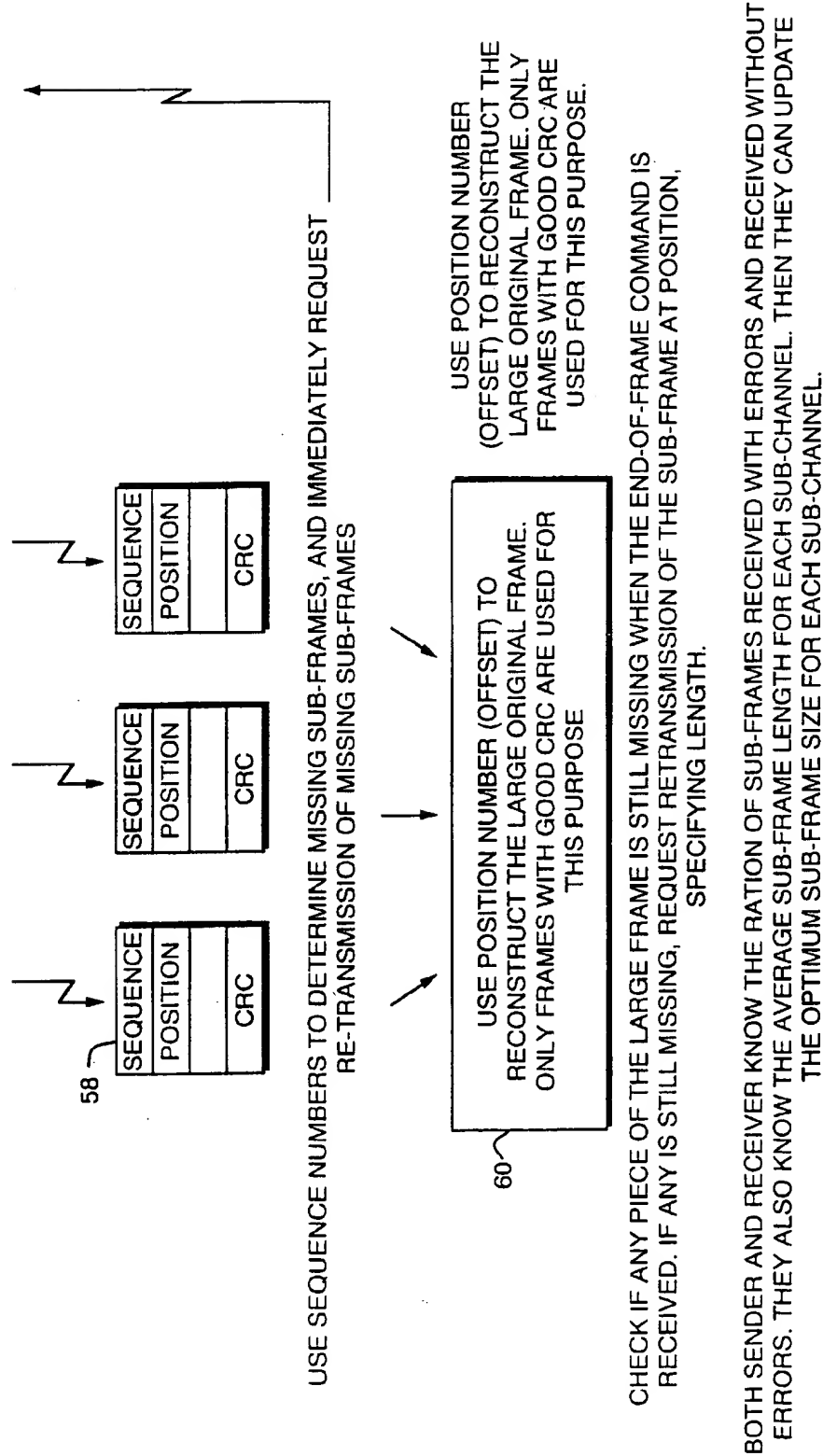


FIG. 4

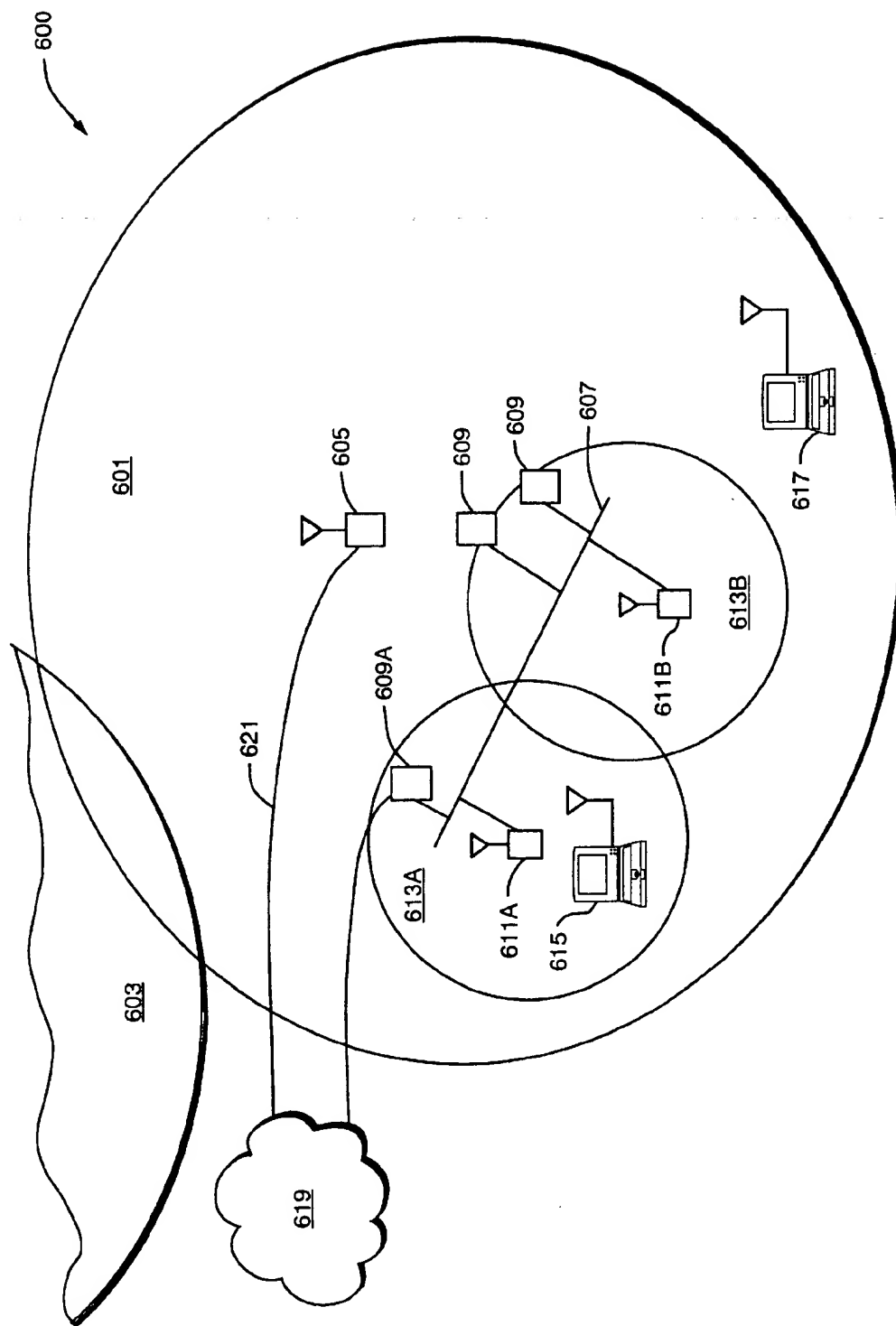


FIG. 5

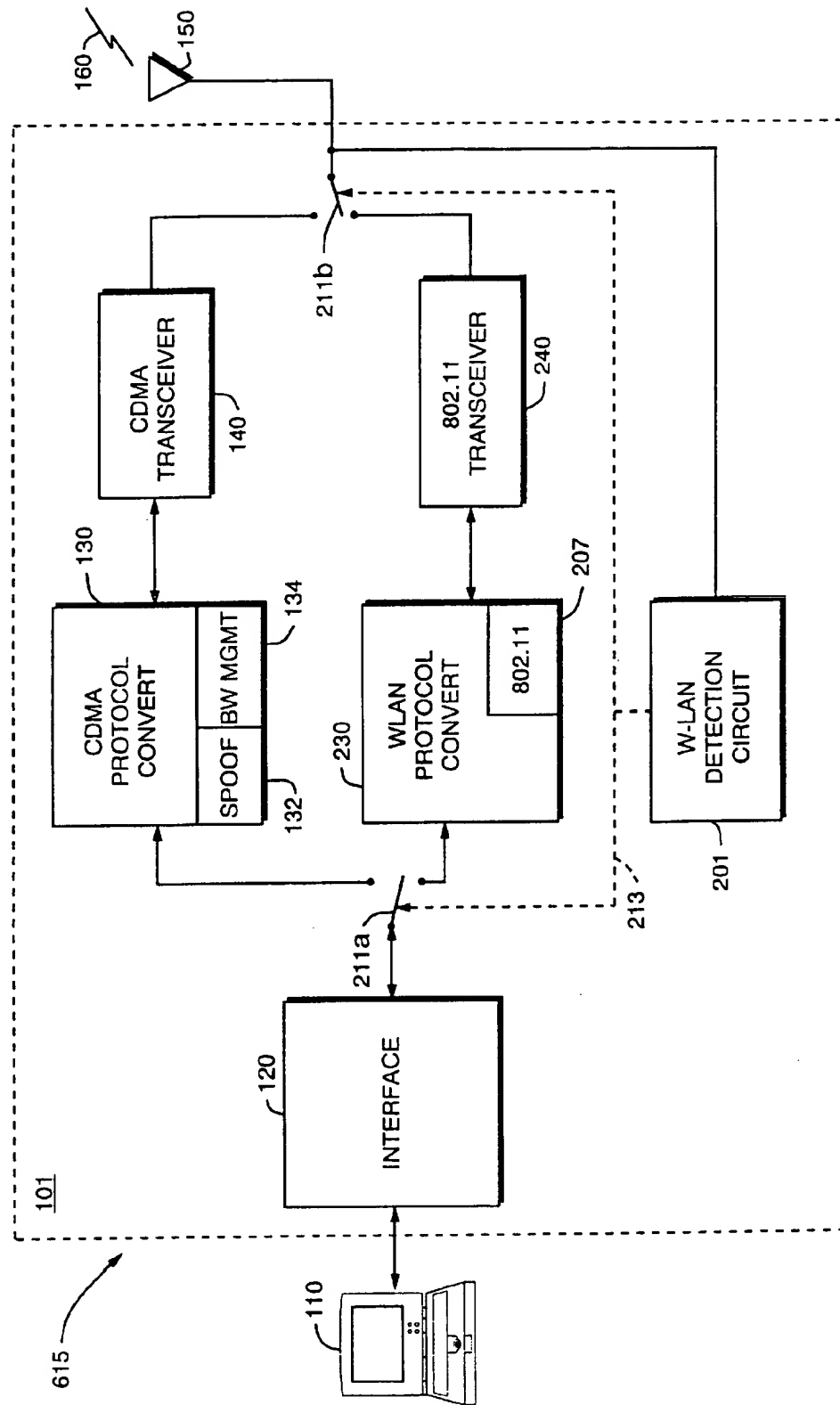


FIG. 6

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DUAL MODE SUBSCRIBER UNIT FOR SHORT RANGE, HIGH RATE AND LONG RANGE, LOWER RATE DATA COMMUNICATIONS

BACKGROUND OF THE INVENTION

The widespread availability of personal computers at low cost has led to a situation where the general public increasingly demands access to the Internet and other computer networks. A similar demand exists for wireless communications in that the public increasingly demands that cellular telephones be available at low cost with ubiquitous coverage.

As a result of its familiarity with these two technologies, the general population now increasingly wishes to not only access computer networks, but to access such networks in wireless fashion as well. This is of particular concern to users of portable computers, laptop computers, hand-held personal digital assistants (PDAs) and the like, who would prefer and indeed now expect to be able to access such networks with the same convenience they have grown accustomed to when using their cellular telephones.

Unfortunately, there still is no widely available satisfactory solution for providing low cost, broad geographical coverage, high speed access to the Internet and other networks using the existing wireless infrastructure which has been built at some expense to support cellular telephony. Indeed, at the present time, the users of wireless modems that operate with the existing cellular telephone network often experience a difficult time when trying to, for example, access the Internet to view web pages. The same frustration level is felt in any situation when attempting to perform other tasks that require the transfer of relatively large amounts of data between computers.

This is at least in part due to the architecture of cellular telephone networks, which were originally designed to support voice communications, as compared to the communications protocols in use for the Internet, which were originally optimized for wireline communication. In particular, the protocols used for connecting computers over wireline networks do not lend themselves well to efficient transmission over standard wireless connections.

For example, cellular networks were originally designed to deliver voice grade services, having an information bandwidth of approximately three kilohertz (kHz). While techniques exist for communicating data over such radio channels at the rate of 9600 kilobits per second (kbps), such low frequency channels do not lend themselves directly to transmitting data at rates of 28.8 kbps or even the 56.6 kbps that is now commonly available using inexpensive wireline modems. These rates are presently thought to be the minimum acceptable data rates for Internet access.

This situation is true for advanced digital wireless communication protocols as well, such as Code Division Multiple Access (CDMA). Even though such systems convert input voice information to digital signals, they too were designed to provide communication channels at voice grade bandwidth. As a result, they use communication channels that may exhibit a bit error rate (BER) as high as one in one thousand bits in multipath fading environments. While such a bit error rate is perfectly acceptable for the transmission of voice signals, it becomes cumbersome for most data transmission environments.

Unfortunately, in wireless environments, access to channels by multiple subscribers is expensive and there is

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competition for them. Whether the multiple access is provided by the traditional Frequency Division Multiple Access (FDMA) using analog modulation on a group of radio carriers, or by newer digital modulation schemes that permit sharing of a radio carrier using Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA), the nature of the cellular radio spectrum is such that it is a medium that is expected to be shared. This is quite dissimilar to the traditional environment for data transmission, in which the wireline medium is relatively inexpensive to obtain, and is therefore not typically intended to be shared.

On the other hand, wireless local area networks (W-LANs) have been developed to allow communications between users over a relatively small range without the need for a physical connection, or alternatively, to allow communications between a wired LAN and wireless users. W-LANs typically have a much smaller range and higher data rates.

A newly accepted standard, IEEE 802.11, specifies a protocol for the media access control (MAC) and physical (PHY) layers of a wireless LAN. As with cellular systems, a W-LAN connection can be handed off from one area of coverage (a "basic service set" in IEEE 802.11 parlance) to the next. A good description of wireless LANs, and the IEEE 802.11 standard in particular, may be found in Geier, J., *Wireless LANs* (Macmillan Technical Publishing, 1999).

SUMMARY OF THE INVENTION

Wireless LANs are generally private networks, that is they are installed, owned, and maintained by a private party, such as a business, educational institution or home owner. Such networks are therefore generally cheaper to access than long range networks which utilize shared public access frequencies licensed by a government authority to complete a connection, and which generally require subscriber fees.

In addition, W-LANs typically operate at a much faster data rate than the long range network. However, as the word "local" implies, the range of a W-LAN is rather limited—typically tens or hundreds of feet, as compared to several miles for a long range cellular telephone network.

It would therefore be desirable to have a device which can automatically select the cheaper and faster W-LAN when possible, e.g., when within its range, and to resort to the long range cellular network when access to the W-LAN is not possible or practical. Previously, two devices would have been required, one for accessing the W-LAN and one for accessing the long range network. At best, these two devices could fit into two slots in, for example, a laptop computer, requiring the user to select, either through software or hardware, which device, and hence, which network to access. The user might typically then have to disconnect one of the devices to install the other, and manually reconfigure the computer.

The present invention, on the other hand, is a single device which connects directly to a W-LAN using a protocol such as IEEE 802.11 when such a connection is possible, and automatically reverts to connecting to the long range network only when out of range of the W-LAN base stations.

Thus, the same equipment can be used without any reconfiguration and even without the knowledge of the user. For example, when the user is on a company campus and within range of the less expensive, faster W-LAN, the user's laptop or PDA automatically communicates with the W-LAN. If the user leaves the office, for example, for lunch, or at the end of the day, heads home, the same laptop or PDA, being out of range of the W-LAN, will automatically

communicate instead with the wider range, more expensive cellular network.

Therefore, the present invention is also a method which uses a first wireless digital communication path and a second wireless digital communication path for coupling data communication signals with a local wireless transceiver at a first site. The second digital communication path provides wider coverage and a slower communication rate than the first digital communication path. The local wireless transceiver conducts wireless communications with a remote wireless transceiver at a second site.

One of the wireless communication path is selected upon a request to establish a communication session between the first and second sites by first determining whether the first wireless digital communication path is available.

In one embodiment, the first wireless communication path comprises a wireless LAN connection, preferably using carrier sense multiple access with collision avoidance (CSMA/CA), preferably according to the IEEE 802.11 specification. The second wireless communication path comprises a cellular connection. Access costs associated with the first wireless communication path are smaller than access costs associated with the second wireless communication path. Preferably, access to the first wireless communication path is essentially free, excluding expenses such as set-up and maintenance costs, while access to the second wireless communication path can be subscription-based.

The local wireless transceiver can be a single transceiver which is capable of communicating with a second site or destination over both wireless communication paths. Alternatively, the local wireless transceiver can comprise two transceivers, one for each communication path.

In one embodiment, the first wireless communication path is a private network. Conversely, the second wireless communication path can be a public network, in which channels are allocated centrally.

In one embodiment, the step of determining whether the first wireless communication mode is available is performed by passive scanning, such as by detecting a beacon signal. In another embodiment, active scanning is used, for example, by transmitting a probe request message and detecting a probe response message in response to the probe request which indicates the presence of the first wireless communication path. In yet another embodiment, determining whether the first wireless communication path is available comprises simply detecting activity on the first wireless communication path.

If the first wireless digital communication mode is available, a communication session between the first and second sites using the first wireless digital communication path is established.

On the other hand, if the first wireless digital communication path is not available, a communication session between the first and second sites using the second wireless digital communication path is established. In this case, the local wireless transceiver is controlled to make it appear to the second wireless digital communication path as though the bandwidth were continuously available during the communication session, irrespective of any actual need to transport data communication signals between said first and second sites. In the absence of such a need to transport data communication signals between the first and second sites, the bandwidth is made available for wireless communication by other wireless transceivers.

In one preferred embodiment, the second wireless digital communication path is provided by establishing a logical

connection using a higher layer protocol, such as a network layer protocol, from a subscriber unit, such as may be connected to a portable computer node, to an intended peer node, such as another computer. The network layer logical connection is made through a wireless channel which provides a physical layer connection between the portable computer node, through a base station, and the intended peer node. In response to relatively low utilization of the wireless channel, the physical layer channel is released while maintaining the appearance of a network layer connection to the higher level protocols.

This has two consequences. First, it frees wireless channel bandwidth for use by other subscriber units, without the overhead associated with having to set up an end to end connection each time that data needs to be transferred. In addition, and perhaps more importantly, by allocating wireless channels only when needed, the bandwidth necessary to provide a temporary but very high speed connection is available at critical times. These may occur, for example, when a particular subscriber unit requests that a web page file be downloaded from the Internet.

More specifically, the technique, which is here called spoofing, involves stripping off the lower layers of the protocol while reformatting higher layer messages for transmission using a more efficient CDMA based encapsulated protocol.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts, throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIG. 1 is a block diagram of a system in which a portable device such as a laptop computer is making use of a protocol converter according to the invention to connect to a computer network over a wireless cellular link.

FIG. 2 is a diagram depicting how network layer data frames are divided among multiple physical links or channels.

FIG. 3 is a more detailed diagram showing how network layer frames are divided into subframes by a protocol converter located at a sender.

FIG. 4 is a continuation of the diagram of FIG. 3.

FIG. 5 is a schematic diagram of a short range, high speed wireless LAN overlapping with a longer range, lower speed wireless communication network.

FIG. 6 is a high-level block diagram of a subscriber unit of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning attention now to the drawings more particularly, FIG. 1 is a block diagram of a system 10 for implementing high speed data communication over a cellular link according to the invention. The system 10 consists of a remote or subscriber unit 20, multiple bi-directional communication links 30, and a local or service provider unit 40.

The subscriber unit 20 connects to terminal equipment 22 such as a portable or laptop computer, hand held Personal Digital Assistant (PDA) or the like, via a computer interface 24 such as a modem. The interface 24 in turn provides data

to a protocol converter 25, which in turn provides data to a multichannel digital transceiver 26 and antenna 27.

The interface 24 receives data from the computer 20, and together with appropriate hardware and/or software, converts it to a format suitable for transmission such as in accordance with known communication standards. For example, the interface 24 may convert data signals from the terminal equipment 22 to a wireline physical layer protocol format such as specified by the Integrated Services Digital Network (ISDN) standard at rates of 128 kbps, or the Kflex standard at rates of 56.6 kbps. At a network layer, the data provided by the interface 24 is preferably formatted in a manner consistent with suitable network communication protocols such as TCP/IP to permit the terminal equipment 22 to connect to other computers over networks such as the Internet. This description of the interface 24 and protocols is exemplary only and it should be understood that other protocols can be used.

The protocol converter 25 implements an intermediate protocol layer suitable for converting the data provided by the interface 24 to a format appropriate for the multichannel transceiver 26 according to the invention, and as is described in greater detail below.

The multichannel digital transceiver 26 provides access to one or more physical communication links such as the illustrated radio channels 30. The physical links are preferably known wireless communication air interfaces using digital modulation techniques such as Code Division Multiple Access (CDMA) standard specified by IS-95. It should be understood that other wireless communication protocols and other types of links 30 may also be used to advantage with the invention.

The channels 30 represent one or more relatively slower communication channels, such as operating at a 9.6 kbps rate typical of voice grade communication. These communications channels may be provided by a single wide bandwidth CDMA carrier such as having a 1.25 MegaHertz bandwidth, and then providing the individual channels with unique orthogonal CDMA codes. Alternatively, the multiple channels 30 may be provided by single channel communication media such as provided by other wireless communication protocols. However, what is important is that the net effect is that the channels 30 represent multiple communication channels that may be adversely effected by significant bit error rates that are unique to each link 30.

An "error" as described herein is a bit error perceived at the higher layer such as the network layer. The invention only strives to improve the system level bit error rate, and does not attempt to guarantee absolute data integrity.

On the local provider unit, the service provider equipment 40 may for example be implemented at a wireless Internet Service Provider (ISP) 40-1. In this case, the equipment includes an antenna 42-1, a multichannel transceiver 44-1, a protocol converter 46-1, and other equipment 48-1 such as modems, interfaces, routers, and the like which are needed for the ISP to provide connections to the Internet 49-1.

At the ISP 40-1, the multichannel transceiver 44-1 provides functions analogous to the multichannel transceiver 26 of the subscriber unit, but in an inverse fashion. The same is true of the protocol converter 46-1, that is, it provides inverse functionality to the protocol converter 25 in the subscriber unit 20. The ISP 40-1 accepts data from the protocol converter 46-1 in the TCP/IP frame format and then communicates such data to the Internet 49-1. It should be understood that the configuration of the remaining ISP equipment 48-1 may take any number of forms such as a

local area networks, multiple dial up connections, T1 carrier connection equipment, or other high speed communication links to the Internet 49-1.

Alternatively, the provider 40 may function as a radio base station in a cellular telephone system to permit a dial-up connection between the terminal equipment 22 and a server 49-2. In this instance, the base station 40-2 includes an antenna 42-2, multichannel transceiver 44-2, and protocol converter 46-2 providing one or more connections to a public switched telephone network (PSTN) 48-2, and ultimately to the server 49-2.

In addition to the illustrated implementations 40-1, 40-2, there may be various other ways of implementing the provider 40 in order to provide a connection to data processing equipment from the terminal equipment 22.

Attention is now turned to the functions of the protocol converters 25 and 46, which can be thought of as an intermediate layer within the context of the Open System Interconnect (OSI) model for communication. In particular, the protocol converter provides a bandwidth management functionality 29 implemented between a physical layer such as that provided by the CDMA protocol in use with the multichannel transceivers 26 and a network layer protocol such as TCP/IP providing connections between the terminal equipment 22 and the Internet 49-1 or server 49-2.

The bandwidth management functionality 29 preferably provides a number of functions in order to keep both the physical layer and network layer connections properly maintained over multiple communication links 30. For example, certain physical layer connections may expect to receive a continuous stream of synchronous data bits regardless of whether terminal equipment at either end actually has data to transmit. Such functions may also include rate adaption, bonding of multiple channels on the links, spoofing, radio channel setup and takedown.

The present invention is more particularly concerned with the technique used by the protocol converters 25 and 46 for adjusting the frame size of individual channels used over each of the multiple links 30 in order to improve the effective throughput rate between a sender and a receiver in a bit error rate prone environment. It should be understood in the following discussion that the connections discussed herein are bidirectional, and that a sender may either be the subscriber unit 22 or the provider unit 40.

More specifically, the problem addressed by the present invention is shown in FIG. 2. The frame 60 as received at the receiver end must be identical to the frame 50 originating at the sender. This is despite the fact that multiple channels are used with much higher bit error rates, with the received frame 60 being transmitted reliably with a bit error rate of 10^{-6} or better as is typically required in TCP/IP or other network layer protocols. The present invention optimizes the effective data throughput such that the received frames 60 are not affected by the experienced bit error rate performance of network layer connections.

It should be understood that another assumption is that the individual channels 30-1, 30-2 . . . 30-N may experience different bit error rate levels both over time and in an average sense. Although each of the channels 30 may operate quite similarly, given the statistical nature of errors, identical behavior of all of the channels 30 is not assumed. For example, a specific channel 30-3 may receive severe interference from another connection in a neighboring cell, and be capable of providing only a 10^{-3} whereby other channels 30 may experience very little interference.

In order to optimize the throughput for the system 10 on a global basis, the invention also preferably optimizes the

parameters of each channel 30 separately. Otherwise, a relatively good channel 30-1 might suffer down speed procedures required to accommodate a weaker channel 30-3.

It should also be understood that the number of channels 30 that may be needed to carry a single data stream such as a rate of 128 kbps at a given point in time may be relatively large. For example, up to 20 channels 30 may be assigned at a particular time in order to accommodate a desired data transfer rate. Therefore, the probability of significantly different characteristics in any given one of the channels 30 is high.

Turning attention now more particularly to FIG. 3, the operations of the protocol converter 25 or 46 at the sender will be more particularly described. As shown, the input frame 50 as received from the network layer is relatively large, such as for example 1480 bits long, in the case of a TCP/IP frame.

The input frame 50 is first divided into a set of smaller pieces 54-1, 54-2. The size of the individual pieces 54 are chosen based upon the optimum subframe size for each of the channels 30 available. For example a bandwidth management function may make only a certain number of channels 30 available at any time. A subset of the available channels 30 is selected, and then the optimum number of bits for each subframe intended to be transmitted over respective one of the channels, is then chosen. Thus, as illustrated in the figure, a given frame 54-1 may be divided into pieces associated with four channels. At a later time, there may be nine channels 30 available for a frame, with different optimum subframe sizes for the piece 54-2.

Each of the subframes 56 consists of a position identifier 58a, a data portion 58b, and a trailer typically in the form of an integrity checksum such as a cyclic redundancy check (CRC) 58c. The position identifier 58a for each subframe indicates the position within the associated larger frame 50.

The subframes 56 are then further prepared for transmission on each channel 30. This may be done by adding a sequence number related to each channel at the beginning of each subframe 56. The subframe 56 is then transmitted over the associated channel 30.

FIG. 4 illustrates the operations performed at the receive side. The subframes 56 are first received on the individual channels 30. A subframe 56 is discarded as received if the CRC portion 58c is not correct.

The sequence numbers 58d of the remaining frames 56 are then stripped off and used to determine whether any subframes 56 are missing. Missing subframes 56 can be detected by comparing the received sequence numbers 58d. If a sequence number is missing, it is assumed that the associated subframe 56 was not received properly. It should be understood that appropriate buffering of data and subframes 56 is typically required in order to properly receive the subframes 56 and determine if there are any missing sequence numbers depending upon the transmission rates, number of channels 30 and propagation delays in effect.

Upon the detection of a missing subframe 56, retransmission of the missed subframe is requested by the receiving end. At this point, the transmitting end reperforms transmission of the missing subframe.

Once all of the subframes 56 are received, the position number 58a is used to arrange the data from the subframes 56 in the proper order to construct the output received frame 60.

At this point, also, if any piece of the large output frame 60 is still missing, such as when an end of frame command

is encountered, retransmission of the corresponding subframe can also be requested at the indicated position, specifying a length for the missing piece.

Because of the use of both the position and sequence numbers, the sender and receiver know the ratio of the number of subframes received with errors to the number of frames received without errors. Also, the receiver and sender know the average subframe length for each channel. The optimum subframe size can thus be determined for each channel from these Parameters as is described more fully in U.S. Pat. No. 6,236,647, filed on Feb. 24, 1998, entitled "Dynamic Frame Size Adjustment and Selective Reject On a Multi-Link Channel to Improve Effective Throughput and Bit Error Rate," incorporated herein by reference in its entirety, and assigned to Tantivy Communications Corp., the assignee of the present application.

FIG. 5 illustrates a short range, high speed wireless LAN (W-LAN) overlapping with a longer range, lower speed wireless cellular communication network ("long range network"). Specifically, within the longer range, lower speed system, which may be a digital cellular mobile telephone system, there are multiple long range regions or "cells" 601 and 603 which provide coverage throughout a given physical area. The range or coverage for each cell 601, 603 is on the order of, for example, greater than one mile radius.

A cellular base station 605 transmits and receives data through its antenna 171 to mobile units located within its associated cell 601. The base station 605 is connected to a public network 619 such as the public switched telephone network (PSTN) or preferably a point of presence (POP) or other data connection 621 to the Internet.

Shown within the cell 601 associated with base station 605 is a wireless local area network (W-LAN) 607. Several terminals or computers 609 are connected directly to the W-LAN 607, including a gateway 609A which is also connected to the public network 619 via any well-known means 621. In addition, two wireless LAN hubs 611A, 611B are connected to the LAN 607. Each wireless LAN hub 611 has a region of coverage 613A, 613B; the coverage area of the two hubs 611A, 611B may overlap as shown in FIG. 5. The regions of coverage 613A, 613B are generally of the order of tens or hundreds of feet, which is significantly smaller than the cells 601, 603 associated with the long range network. In this respect, it is particularly important to note that FIG. 5 is not drawn to scale.

Also shown are two subscriber units or terminals, such as portable computers, employing the present invention. The first terminal 615 is within range 613A of a wireless LAN base station 611, while the second terminal 617 is outside the range of either wireless LAN base station 611A, 611B but within the range 601 of the long range network base station 605.

Because communication within the short range wireless LAN 613A or 613B is faster and less expensive as compared to the long range network, it is desirable to communicate using the short range path, i.e., the W-LAN protocol, rather than the more costly long range network, when a user's computer terminal 615 is within range of a W-LAN base station 611, i.e., within the region of coverage 613A, 613B.

On the other hand, it is desirable that a terminal such as terminal 617, which is not within range of a wireless LAN base station 611, automatically communicate through the long range network's base station 605.

Thus it is a primary feature of the present invention that a terminal such as 615 or 617 detects the presence or availability of a wireless LAN hub 611A or 611B, such as an

IEEE 802.11-compliant W-LAN hub. This can be done in several ways. For example, IEEE 802.11 specifies that a beacon frame should be transmitted at regular intervals. A terminal 615, 617 can detect the beacon frame by waiting a minimum period of time equal to the beacon interval. See, for example, Geier, J., *Wireless LANs*, pages 137 and 149, (Macmillan Technical Publishing, 1999), incorporated herein by reference, which describes how a W-LAN beacon signal is formatted.

Alternatively, a terminal such as 615 may actively transmit a probe request frame. A wireless LAN base station 611 receiving such a probe request frame will respond with a probe response frame. Receipt of the probe response frame by the terminal 615 indicates accessibility of the wireless LAN, and the terminal 615 will use the wireless LAN and bypass the long range network.

If, on the other hand, no beacon is received within the specified time period or no probe response frame is returned from the base frame, as would be the case with terminal 617, the terminal assumes that the wireless LAN base stations 611 are not accessible and instead communicates with the long range base station 605 using the long range network protocol rather than IEEE 802.11 protocol.

Yet another alternative is simply to listen for activity on the wireless LAN 611. If no activity is heard, the terminal 615, 617 assumes that the LAN is not accessible, and uses the long range communication system.

FIG. 6 shows a terminal 615 which includes a subscriber unit 101 incorporating the features of the present invention. A user at this terminal 615 desires to communicate with a second site using a portable computer 110, PDA or other similar device. The computer 110 is connected to the subscriber unit 101. For example, the subscriber unit 101 may be a PCMCIA card which plugs into a PCMCIA slot, or it may connect to the computer 110 with a modem cable.

The subscriber unit 101 itself preferably consists of an interface 120, a CDMA protocol converter 130 that performs various functions including spoofing 132 and bandwidth management 134 as described earlier, a CDMA transceiver 140, a W-LAN protocol converter 230, a W-LAN transceiver 240, a W-LAN detection circuit 201, path selection switches 211A, 211B, and a subscriber unit antenna 150. The various components of the subscriber unit 101 may be realized in discrete devices or as an integrated unit. For example, an existing conventional computer interface 120 such as the PCMCIA, ISA bus, PCI bus, or any other computer interface may be used together with existing transceivers 140, 240. In this case, the unique functions are provided entirely by the protocol converters 130, 230 which may be sold as separate devices, the W-LAN detection circuit 201 and the mode selection switches 211A, 211B.

Alternatively, the interface 120, protocol converters 130, 233, and transceivers 140, 240 may be integrated as a complete unit and sold as a single subscriber unit device 101. Other types of interface connections such as Ethernet, ISDN, or still other data connections may be used to connect the computing device 110 to the protocol converter 130.

The CDMA protocol converter 130 performs spoofing 132 and basic bandwidth management 134 functions. In general, spoofing 132 consists of insuring that the subscriber unit 101 appears, to the terminal equipment 110, to be connected to the public network 619 (FIG. 5) on the other side of the base station 605 at all times.

The bandwidth management function 134 is responsible for allocating and deallocating CDMA radio channels 160 as required. Bandwidth management 134 also includes the

dynamic management of the bandwidth allocated to a given session by dynamically assigning sub-portions of the CDMA radio channels 160 in a manner using a protocol such as that described previously.

The CDMA transceiver 140 accepts the data from the protocol converter 130 and reformats this data in appropriate form for transmission through the subscriber unit antenna 150 over the radio link 160. The CDMA transceiver 140 may operate over only a single 1.25 MHz radio frequency channel or, alternatively, may be tunable over multiple allocatable radio frequency channels.

CDMA signal transmissions are then received and processed by the base station equipment 605 (FIG. 5). The base station 605 then couples the demodulated radio signals to, for example, the public network 619 in a manner which is well known in the art. For example, the base station 605 may communicate with the public network 619 over any number of different efficient communication protocols such as primary rate, ISDN, or other LAPD based protocols such as IS-634 or V5.2.

It should also be understood that data signals travel bidirectionally across the CDMA radio channels 160. In other words, data signals received from the public network 619 are coupled to the portable computer 110 in a forward link direction, and data signals originating at the portable computer 110 are coupled to the public network 619 in a so-called reverse link direction.

Continuing to refer to FIG. 6 briefly, in the long range, lower data rate mode, the spoofing function 132 involves having the CDMA transceiver 140 loop back synchronous data bits to spoof the terminal equipment 110 into believing that a sufficiently wide wireless communication link 160 is continuously available. However, wireless bandwidth is allocated only when there is actual data present from the terminal equipment to the CDMA transceiver 140. Therefore, the network layer need not allocate the assigned wireless bandwidth for the entirety of the communications session. That is, when data is not being presented upon the terminal equipment to the network equipment, the bandwidth management function 134 deallocates initially assigned radio channel bandwidth 160 and makes it available for another transceiver and another subscriber unit 101.

W-LAN detection circuit 201 detects the presence or availability of a W-LAN base station 611 using, for example, one of the techniques previously discussed. If no W-LAN base station is detected, switches 211A and 211B are controlled by the detection circuit 201 such that the CDMA protocol converter 130 is switched in along with the CDMA transceiver 140.

If, on the other hand, a W-LAN is detected, switches 211A and 211B are switched to the position shown to utilize the W-LAN protocol converter 230 and transceiver 240, which are preferably IEEE 802.11-compliant. Note that the path switches 211A, 211B may be implemented in software or hardware, or a combination of hardware and software. Other functions may also be implemented in hardware and/or software which may further be shared by the W-LAN and CDMA sections where appropriate.

Furthermore, the long-range, low-speed CDMA path could be selected after failure to communicate over the short-range, high speed path for any reason, for example, the inability to successfully complete a communication after some predetermined time period.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various

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changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

What is claimed is:

1. For use with a digital communication network having a first wireless digital communication path and a second wireless digital communication path for coupling data communication signals with a local wireless transceiver at a first site, the second digital communication path providing wider coverage and a slower communication rate than the first digital communication path, the local wireless transceiver being operative to conduct wireless communications with a remote wireless transceiver at a second site, a method of selecting a wireless communication path comprising the steps of:

- a) in response to a request to establish a communication session between said first and second sites, determining whether the first wireless digital communication path is available;
- b) establishing a communication session between the first and second sites using the first wireless digital communication path if the first wireless digital communications path is available;
- c) establishing a communication session between the first and second sites using the second wireless digital communication path if the first wireless digital communication path is not available;
- d) when a communication session has been established via the second wireless digital communication path, controlling the local wireless transceiver to appear to the second wireless digital communication path as though the bandwidth is continuously available during said communication session for wireless communications between said local and remote transceivers, irrespective of the need to transport data communication signals between said first and second sites; and
- e) when a communication session has been established via the second wireless communication path, in the absence of said need to transport data communication signals between said first and second sites, making said bandwidth available for wireless communication by another wireless transceiver of said digital communication network.

2. A method as in claim 1 additionally comprising the step of:

- (f) maintaining a connection at a network layer above a data link layer by establishing a lower level connection and using radio frequency bandwidth only when required.

3. The method of claim 1 wherein communication of data is between a sender at the first site and a receiver at the second site, over one or more communication channels, the data being provided in a frame, the method further comprising the steps of:

- dividing a frame into subframes according to an optimum subframe size;
- sending the subframes over a communication channel;
- determining the number of subframes received at the receiver in error; and
- determining the optimum subframe size for the communication channel based upon the determined number of subframes received in error which were attempted to be communicated over that channel.

4. The method of claim 3 wherein the step of sending the subframes additionally comprises sending subframes over multiple distinct communication channels.

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5. The method of claim 4 wherein the steps of determining the number of subframes received, and determining the optimum subframe size additionally comprise determining an error rate in each channel and an optimum number of subframes for each channel individually.

6. The method of claim 1 wherein the first wireless communication path comprises a wireless LAN connection.

7. The method of claim 6 wherein the LAN is according to IEEE 802.11.

8. The method of claim 1 wherein the second wireless communication path comprises a cellular connection.

9. The method of claim 1 wherein access costs associated with the first wireless communication path are smaller than access costs associated with the second wireless communication path.

10. The method of claim 9 wherein access to the first wireless communication path is essentially free.

11. The method of claim 9 wherein access to the second wireless communication path is subscription-based.

12. The method of claim 1 wherein determining whether the first wireless communication path is available comprises detecting a beacon signal.

13. The method of claim 1 wherein determining whether the first wireless communication path is available comprises:

- transmitting a probe request message; and
- detecting a probe response message in response to the probe request.

14. The method of claim 1 wherein determining whether the first wireless communication path is available comprises detecting activity in the first wireless communication path.

15. The method of claim 1 wherein the first wireless communication path comprises a private network.

16. The method of claim 1 wherein the second wireless communication path comprises a public network.

17. The method of claim 1 wherein, in the second wireless communication path, channels are allocated centrally.

18. The method of claim 1 wherein the first wireless communication path uses carrier sense multiple access with collision avoidance (CSMA/CA).

19. An apparatus at a first site for communicating with a second site over a digital communication network having a first wireless digital communication path and a second wireless digital communication path, the second digital communication path providing wider coverage and a slower communication rate than the first digital communication path, comprising:

- a first transceiver for communicating over the first wireless digital communication path;
- a second transceiver for communicating over the second wireless digital communication path;
- a detector for detecting whether the first wireless digital communication path is available; and
- a control circuit which selects the first transceiver for communications over the first wireless digital communication path when the first wireless digital communication path is available, and which selects the second transceiver for communications over the second wireless digital communication path when the first wireless digital communication path is not available, wherein when a communication session has been established via the second wireless digital communication path, the first wireless transceiver is controlled to appear to the second wireless digital communication path as though the bandwidth is continuously available during said communication session for wireless communications between said first and second

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transceivers, irrespective of the need to transport data communication signals between said first and second sites, and

in the absence of said need to transport data communication signals between said first and second sites, said bandwidth is made available for wireless communication by another wireless transceiver of said digital communication network.

20. The apparatus of claim 19, wherein a single transceiver performs both communication over the first wireless digital communication path and over the second wireless digital communication path, the control circuit selecting which path to utilize responsive to the detector.

21. The apparatus of claim 19, wherein communication of data is between a sender at the first site and a receiver at the

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second site, over one or more communication channels, the data being provided in a frame, and wherein

a frame is divided into subframes according to an optimum subframe size;

the subframes are sent over a communication channel;

number of subframes received at the receiver in error is determined; and

the optimum subframe size for the communication channel is determined based upon the determined number of subframes received in error which were attempted to be communicated over that channel.

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